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BASIC INPUTS TO PROBUB MODEL FOR THE EASTERN BERING SEA AND WESTERN GULF OF ALASKA

February 1980

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1. THE NATURE OF RATE COEFFICIENTS AND OTHER INPUT DATA

The species and/or ecological groups used in PROBUB 80-1 are listed in Table 1. Only a few species, such as herring and pollock, are considered as single species; most species are grouped into ecological groups whereby the feeding habits were used as main criterion. Notes on the relative abundance of biomasses of species (i.e. the biomass ratios) in some ecological groups are indicated in Table 1. The species/ecological groups are usually referred to in the latter tables by a single representative species of the group. The "species group space" for "species" 1 to 4 is reserved for special studies of single species which are taken out from a given ecological group and divided into four age (size) groups, when such special studies are conducted.

Table 2 contains various general data on the major species, as extracted from literature and processed reports. Most of these data are not directly used in the model and there are reservations on the validity of some of the data in this table. Species-specific data are summarized in NWAFC's Species Thesaurus (some in reproduction).

The subregions of the PROBUB models 80-1 and 80-2 are shown in Figures 1 and 2. The subregions coincide with new statistical and management areas. The areas of the subregions are given in Table 3. Each statistical/management area along the coast is divided into two subregions: one "shallow" subregion from coast to 500 m depth, and the other deep subregion from 500 m depth to 200 n. miles offshore. The latter boundary is obviously rather arbitrary for many biological distributions.

The monthly rate coefficients, as used in PROBUB 80-1, are given in Table 4. All coefficients in this table are only "mean" coefficients, which are changed in computations in space and time, as influenced by a number of factors (examples of changes are given in Chapter 3 of this report). Fishing intensity (mortality) coefficient is changed at will, depending whether given past fishing conditions are desired or tests will be made to study the influence of proposed fishing regulations. All coefficients refer to whole biomass (and not only on exploitable biomass) and change if age composition of biomass changes for various reasons.

The initial composition of food of the species/groups of species is given in Table 5 for shallow and deep regions. All available pertinent literature was screened for food composition and feeding habits data and observations. To derive at the mean composition of food, the age (size) distribution of biomass has also been taken into account (re. size dependent feeding). This mean food composition is used in the model as a predation vulnerability index and the actual food composition varies with space and time (see Chapter 3 in this report).

2. THE SIMULATION COEFFICIENTS FOR PLANKTON STANDING STOCKS, AND PLANKTON AND BENTHOS AS PRODUCTION BUFFERS

The available data on plankton production and its standing stocks in the Bering Sea and Gulf of Alaska, especially on its spatial and temporal (e.g. seasonal) variations, are very deficient and often contradictory. The available estimates of annual primary production range from in excess of 300 g C/m^2 to lower values such as 150 g C/m^2 "inshore" and 55 g C/m^2 "offshore".

Some of the primary production values reported in the literature are given below. Motoda and Minoda (1974) observed mean primary production on the Bering Sea shelf between Pribilof and Bristol Bay to be 0.4 g C/m^2/day (= 146 g C/m^2/year). Smetanin (1956) reported the following primary production values: northern region 50 to 60 g C/m^2/year, western region, inshore 120 to 150 g C/m^2/year and offshore 35 to 55 g C/m^2/year.

According to Alexander (1978) the primary production in the Bering Sea can be as high as 300 g C/m^2/year. During the spring bloom period, which can last for over one month, 65% of the annual production occurs. This production is not effectively removed by grazing, but most of it sinks to the bottom. Ivanenko (1961) reported production in the Bering Sea during "growing season" as high as 605 g C/m^2 over the shelf and 230 g C/m^2 over deep oceanic area. McRoy and Goering (MS) reported annual mean values as 141 g C/m^2/year over the shelf and 133 g C/m^2/year over deep water, whereas Taguchi (1972) reported shelf water production to be only 89 g C/m^2/year, and central water production as 71 g C/m^2/year.

Meshcheryakova (1963) gives for phytoplankton standing crop in top 25 m between Pribilof and St. Mathews Islands in July over 3 g/m^3 and in June and October 1 to 2 g/m^3. Henrich (1962) gives basic organic production only as 35 g C/m^2/year.

The best summary on the plankton in the Bering Sea is from Motoda and Minoda, 1974, who stated that 80% of the zooplankton standing stock is in the upper 80 meters. They found the mean summer biomass of zooplankton to be 20 to 67 g/m^2, with a mean of 37 g/m^2 in the north central part of the Bering Shelf; 30 g/m^2 in the Bering Sea deep water; 50 g/m^2 in the south central shelf; and 67 g/m^2 on the slope near Pribilof.

Quantitative data on abundant euphausids is nearly entirely absent. Very low values of copepod production such as 115 to 135 g biomass/m^2/year and 14 g C/m^2/year have been reported (Heinrich 1962). Mednikov (1960) reported that 70 to 90% of zooplankton are copepods and gave for zooplankton production and standing stock the following values: production 115 g/m^2/year; standing stocks SE 0.1 to 0.5 g/m^3, W part 1.5 to 2.5 g/m^3. Meshcheriakova (1964) stated that off slopes and near the coast the zooplankton standing crop is 200 to 500 mg/m^3. In the rest of the Bering Sea only in a few areas is the zooplankton standing stock greater than 100 g/m^2; normally in "rich" areas it is only 50 to 100 g/m^2. Furthermore, Meshcheriakova stated that in May zooplankton biomass did not exceed 100 mg/m^3; however, concentrations reaching 300 mg/m^3 were observed evening and night in the surface layer. In shallow areas the zooplankton concentration in June varied between 1 to 10 g/m^2 and in August 10 to 50 g/m^2. By September the zooplankton off St. Matthews Island increased to 10-15 g/m^2, but decreased markedly between Unimak and St. Lawrence Islands.

For comparison Sherman summarized the few available estimates on the zooplankton production along the NE coast of the U.S. in a paper for a fisheries-climate workshop in Columbia, Missouri, April 1976. These estimates, obtained with different methods, ranged between 4 and 200 mg C/m^2/day. The average and plausible value was about 50 mg C/m^2/day, which gave 183 g C/m^2/year or t/km^2/year. This value (and other zooplankton production values) can only be taken as a very approximate estimate, and cannot serve as bases for any other production or its utilization calculations.

The data on benthos and its production are still more deficient from the Bering Sea than the data on plankton. Almost nothing is known on the annual production of different components of benthos. The quantitative data on benthos can be summarized as follows: The total benthos biomass ranges from 55 to 905 g/m^2. The average value for the north central part of the Bering Sea is 170 g/m^2. The overall mean is 100 g/m^2, whereby the highest standing stocks of benthos occurred in depths between 50 and 150 meters. The best summary on Bering Sea benthos is from Alton (1972), which is briefly summarized below.

Density of the benthos is highest in the western and northern parts of the shelf, reaching a maximum average value of 905 g/m^2 in the Chirikov Basin. The lowest value is 55 g/m^2 for the broad shelf of the southeastern Bering Sea where major fisheries take place. (This low value is probably due to heavy predation.) Of the total estimate of food benthos in the Bering Sea (64 million metric tons), only 17 percent (or 11 million metric tons) are accessible to commercial concentrations of demersal fish according to Alton (1972) because of the cold temperatures that prevail in many parts of the sea.

The highest concentrations of benthos occur in intermediate depths 20-150 m. "Fish food" benthos in the southeastern region exceeds 50% of the total benthos and consists predominantly of small clams, polychaetes, and brittelstars.

The brief summary above shows that the productions and biomasses of plankton are ill known and, most importantly, the pathways of these biomasses through the rest of the ecosystem as food sources are very variable in space and time and are equally ill known. However, these biomasses can serve as "production buffers" for the ecosystem in the sense that they, besides being utilized by the smaller (and younger) specimens, can be utilized by larger specimens when other preferred food is scarce. The benthos, however, serves as a steady food source for demersal and semidemersal species. Furthermore, the patchiness of plankton (and benthos) is a factor which affects its availability as a food source and might be one of the causes for aggregation and "feeding migrations" in many species.

The benthos biomass is divided in the model into three groups--predatory benthos, infauna, and epifauna, and their standing stocks are determined with the unique solution (equilibrium standing stock) with the PROBUB model. Many necessary coefficients for benthos are taken from research results from other comparable areas, such as the Barents Sea.

The monthly standing stocks of plankton are simulated with a harmonic formula (given in FORTRAN notations)

P = PYO + PYA * cos (ALP * T - PKA) + PYF * cos (ALPS * T - PKF)

Z = ZOO + ZOA * cos (ALP * T - ZKA) + ZOF * cos (ALPS * T - ZKF)

where: P and Z are monthly mean standing stocks of phyto- and zooplankton in a given region.

PYO and ZOO are corresponding annual mean standing stocks.

PYA and ZOA are main annual magnitudes of changes (first harmonic constants).

PYF and ZOF are secondary annual magnitudes of changes (second harmonic constants).

ALP is main phase speed (30° per month).

ALPS is secondary phase speed (60° per month).

T is time (in month).

PKA and ZKA are main phase lags.

PKF and ZKF are secondary phase lags.

The values for the above harmonic constants for PROBUB 80-1 are given in Table 6. Examples of simulated standing stocks are given in Figure 3.

3. EXAMPLES OF CHANGES IN TIME AND SPACE OF GROWTH COEFFICIENTS AND COMPOSITION OF FOOD

The growth coefficient of biomass is one of the important parameters in biomass based models. It varies in space and time, affected by such factors as temperature, availability of food (partial starvation) and biomass distribution with age (including changes in recruitment) (see further on growth in NOTITIAE COLLATI). Examples of growth coefficient changes with time (monthly changes) for two species, pollock and flathead sole, in subregion 1 are shown in Table 7. Table 8 gives examples of growth coefficient changes in different subregions (i.e. spatial changes) in two months (February and August) for the same species. A detailed analyses of spatial and temporal changes of growth coefficients, their causes and consequences will be reported in other forthcoming reports.

The food composition of any given species varies in space and time, depending on availability of proper food. The food composition also changes with the age (size) of the fish. The food composition is computed in the PROBUB model for each time step and each region, using the prescribed "mean" composition of food (Table 5) as a guidance (for computation procedure see NOTITIAE COLLATI). Examples of food composition changes in space and time for two species, cod and flathead sole, are shown in Tables 9 to 12. Studies of these changes and their causes and consequences will be reported later, together with the results of outputs from the models.

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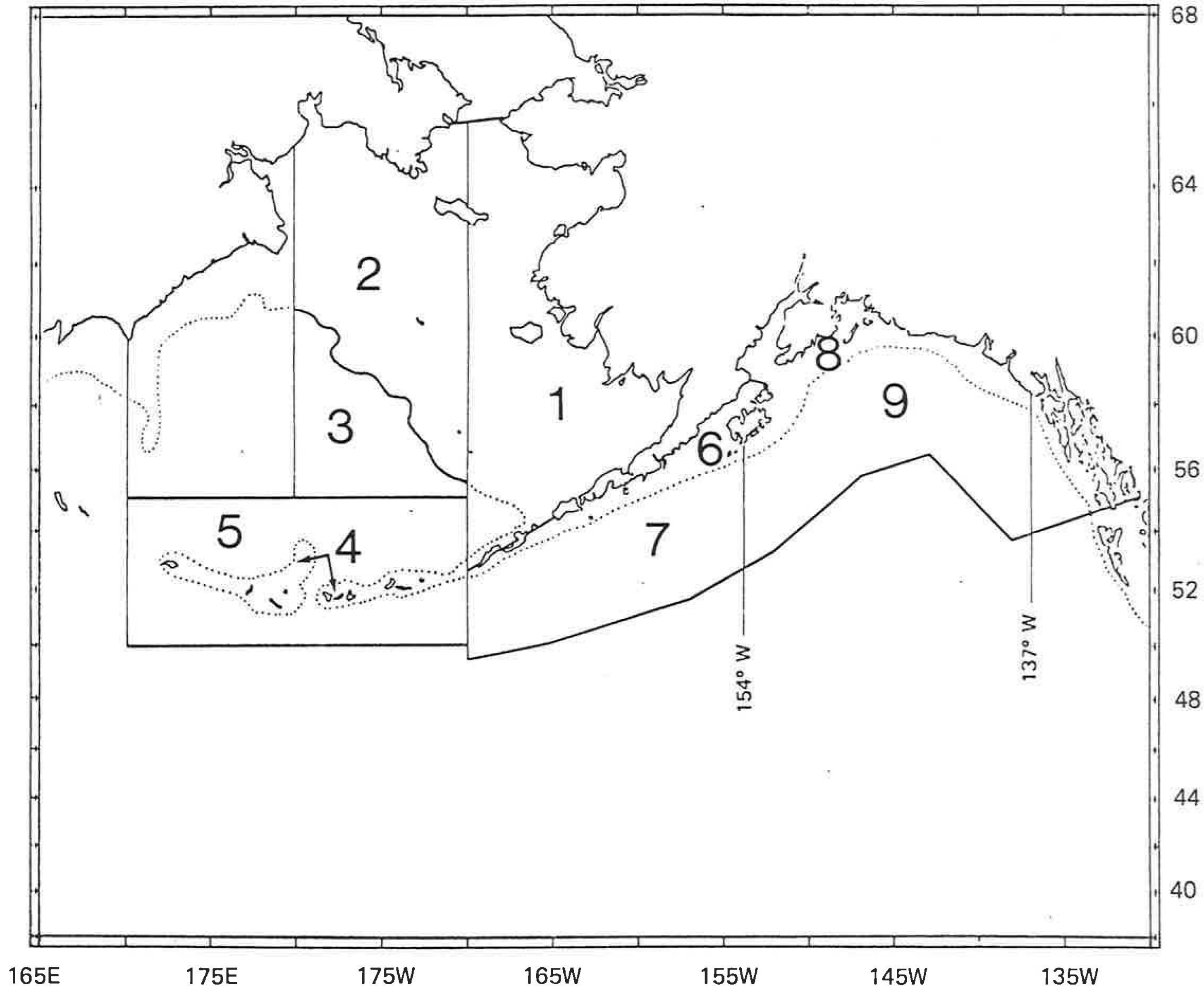


Figure 1.--Subregions of the eastern Bering Sea and western Gulf of Alaska in PROBUB 80-1.

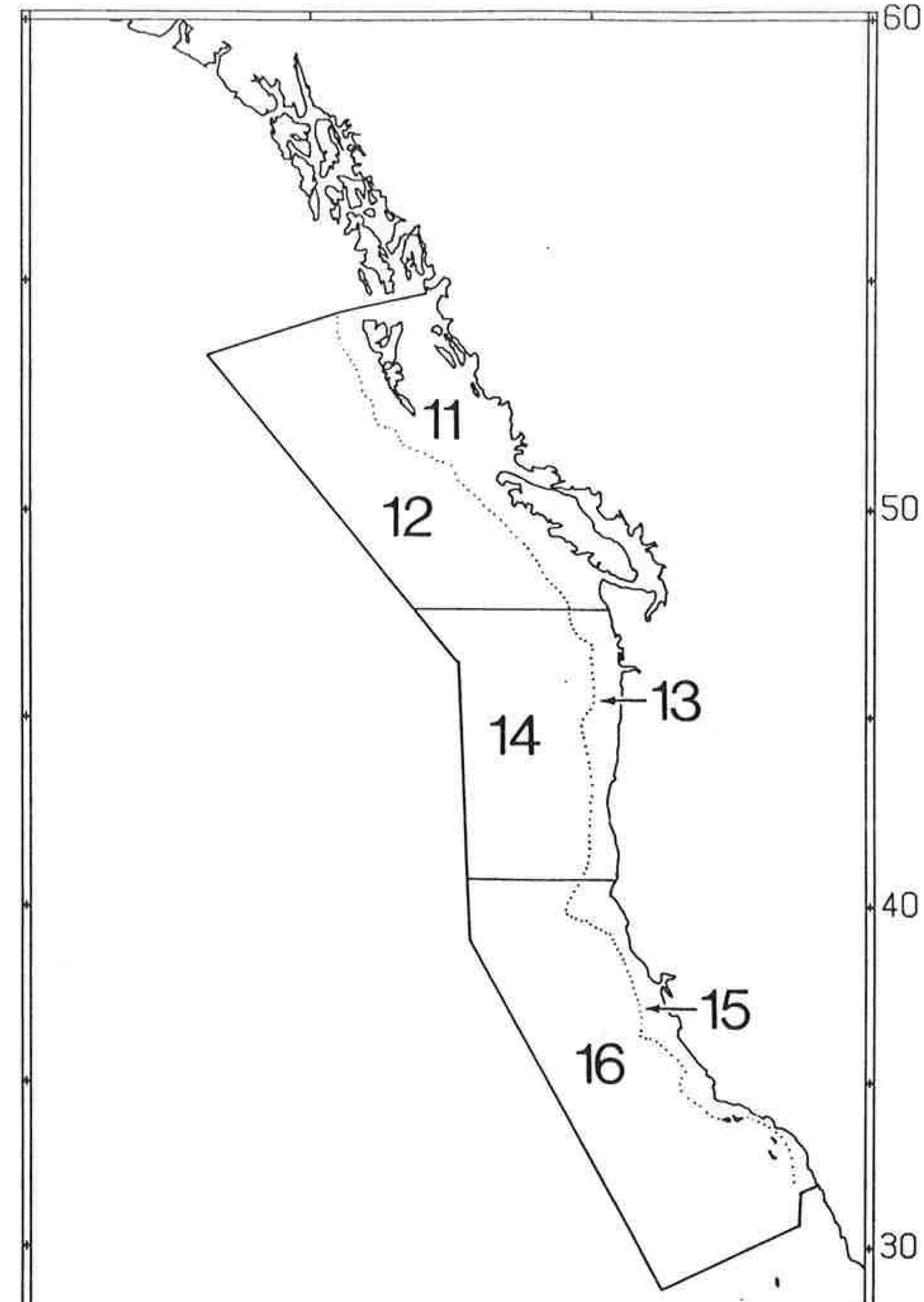
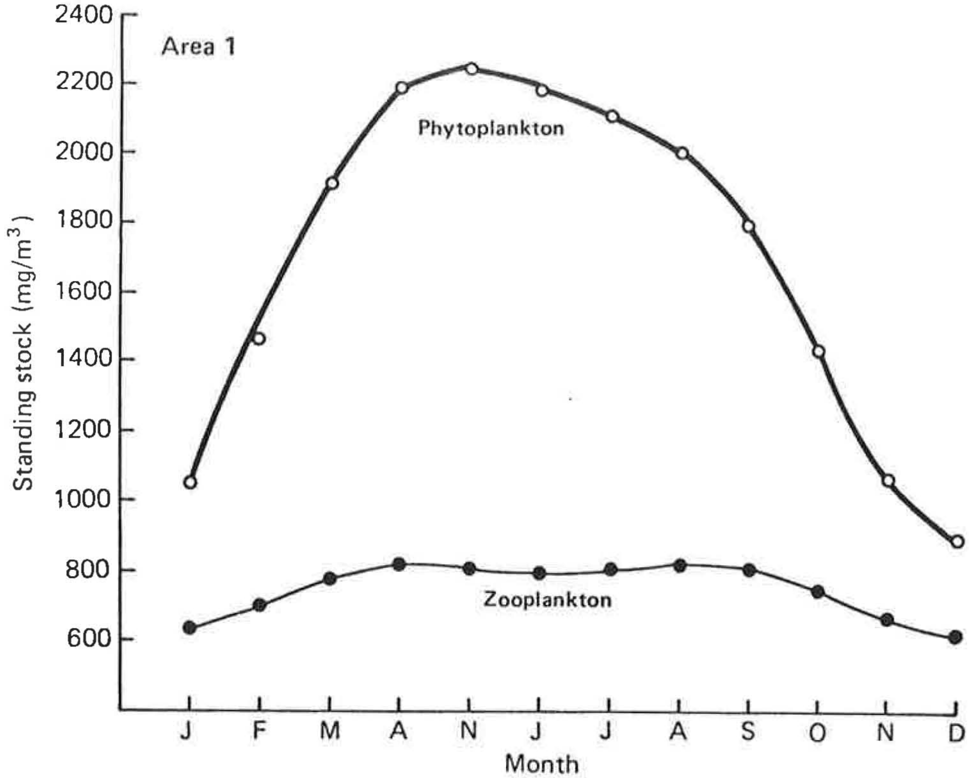


Figure 2.--Subregions of the eastern Gulf of Alaska and U.S. west coast in PROBUB 80-2.



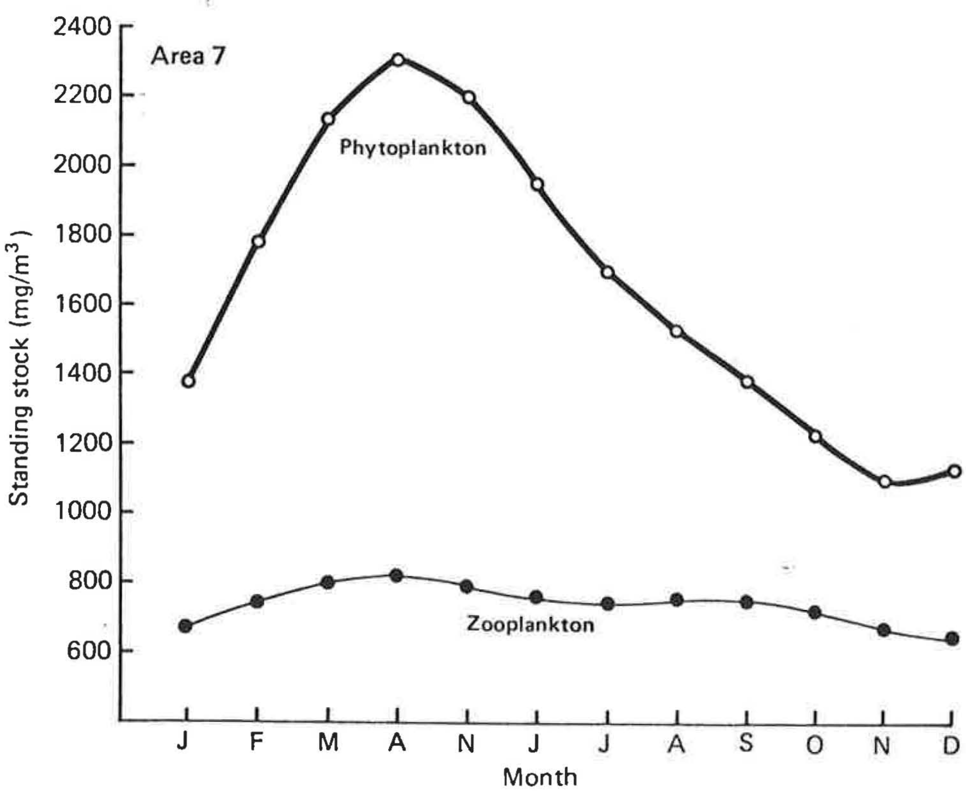


Figure 3.--Annual changes of phytoplankton and zooplankton standing stocks in subregions 1 and 7.

Table 1.--Species, ecological groups and numerical relations within some groups in the Bering Sea and Gulf of Alaska

1 - 4 Species under special study (by age groups) (4 Hake (in West Coast model)).

Demersal (L-"largemouth", S-"smallmouth")

5 - Greenland halibut (turbot), Pacific halibut (L) (ca 3.5:1 in Bering Sea).
6 - Flathead sole, arrowtooth flounder (L) (ca 4:1 in Bering Sea; 1:2 in Gulf of Alaska).
7 - Yellowfin sole (until Vancouver Island), rock sole, Alaska plaice (S) (9:1.5:1 in Bering Sea; 2:8:0.5 in Gulf of Alaska). (Petrale sole, starry flounder, and English sole in West Coast model.)
8 - Other flatfishes (S) (longhead dab, Dover sole, rex sole (last two in Gulf of Alaska)). (Sand dab in West Coast model.)
9 - Cottids and others (e.g. Elasmobranchs, etc.).

Semi-demersal

10 - Pacific cod, saffron cod (saffron cod, polar cod in northern part of Bering Sea)
11 - Sablefish
12 - Pollock
13 - Pacific ocean perch (and other Sebastes spp.)

Pelagic

14 - Herring
15 - Capelin, other smelts, sand lance (sauri, myctophids, lanternfishes in West Coast model).
16 - Atka mackerel (mackerels in West Coast model).
17 - Salmon (5 species, temporary presence) (tunas in West Coast model).
18 - Squids (mainly Gonatids) (Loligo sp. in West Coast model).

Crustaceans

19 - Crabs (King and Tanner crabs)
20 - Shrimp

Benthos

21 - Predatory benthos
22 - Infauna
23 - Epifauna

Plankton

24 - Phytoplankton
25 - Copepods
26 - Euphausids
27 - Ichthyoplankton

Table 2.

Notes on abundant and commercial fish in the Bering Sea and Gulf of Alaska.

Species	Equil. biomass 10^3t	Some earlier estimates of exploited stocks 10^3t	Maximum annual catches 10^3t	Estimated maximum catch (exp.)	Distribution and other notes	Migrations
Turbot (Greenland turbot)	410	140	90	60	Continental slope; winter 600 to 1000 m, summer 200 to 700 m; juveniles on the shelf.	Seasonal depth and north-south migrations.
Halibut		42(BS)	2(BS)		Occurs as far N. as St. Lawrence Island; winter 300 to 600 m; summer 150 to 450 m; juveniles over continental shelf in S. and centr. B.S.; Opt. temp. 3-8°C.	Seasonal depth and north-south migrations. Exchange between B.S. and G. of A.
Flathead sole	700	132	50	70	On slope, deeper than yellowfin sole. Feeds little in winter; spawns in April.	
Arrowtooth flounder (turbot)		33(BS)	25		From N. California to G. of Anadyr. Distr. to 1000 m; major cons. >200 m. Dominant flounder in Gulf of Alaska.	Seasonal depth migration. Immatures in 100 to 200 m in summer.
Yellowfin sole	130	1 to 2 mil.	610	300	From Vancouver Island to Bering Strait. Winter in 120 to 20 m. Spawns in autumn and early winter	Migrates towards NE in May and June.
Rock sole		200	67		From Mexican border to Gulf of Anadyr. In shallower water than yellowfin. Second important in Gulf of Alaska.	Seasonal depth migration.
Alaska plaice		150	7		Over continental shelf in B.S. Feeds little in winter	Seasonal depth migration; winter 100 to 150 m; summer 30 to 100 m.
Other flatfishes						
Longhead dab					(Starry flounder, lemon sole, sand dab, and petrale sole off west coast of America).	
Dover sole	880		(48)	50	From S. California to Gulf of Alaska	
Rex sole					In Gulf of Alaska	
Cottids, elasmobranchs and other demersal species	4,120					
Pacific cod	1030	5% of pollock (might be up to 2 mil.)	59		Shelf and slope from S. Oregon to Gulf of Anadyr. Spawns in deep water (>300 m) in spring and early summer.	Migrates over shelf in summer, where temperature is <8°C.
Saffron cod		30		70	Central and northern part of Bering Sea.	
Sablefish	130	20	26(BS) 37(GA)	20	From Mexican border to Kamchitka. Off California 800 to 1500 m; B.S. 150 to 1200 m. Spawns in winter in deep water; juveniles over shelf.	Extensive N-S migrations.
Pollock	9,210	1 to 2 million in Gulf of Alaska	1.8 million Bering Sea, 62 in Gulf of Alaska	1.2 mil.	From Vancouver Island northward; upper shelf, slope and deep water. Spawns February to June.	To deep water in autumn, back to slope and shelf in spring.
Pacific ocean perch (and other rockfishes)	1,630	110(BS)	74(BS) 110(Aleut) 344(GA)	150	From Mexican border to Gulf of Anadyr. Along the slope and deep water (150 to 1,000 m). Most catch >250 m.	Extensive migration. In shallower water from June to September.
Herring	1,970		132	60		
Capelin, sand lance, other smelts, myctophids (in deep water) and other pelagic.	3,510					
Atka mackerel	1,160		28	25	Gulf of Alaska and eastern Bering Sea	
Salmon				35	Six highly migratory anadromous species.	
Squid	1,270		(10)	20		
Crab	850	122 mil in Bering Sea	9 mil.	20	Southern Bering Sea and around Pribilof and St. Lawrence Island.	
Shrimp	930			3		
Hake		1.8 mil.	170	170	Gulf of California to British Columbia. Spawns off southern California, January to April.	N-S migration; off Oregon in April on the way to north; back to south in November.

Table 3.--Areas of subregions in km^2

Region number	Area	
Bering Sea and western Gulf of Alaska model (PROBUB 80-1)		
1	542,850	(of which 37,650 is deeper than 500 fathoms)
2	422,570	"shallow"
3	203,160	deep
4	88,000	"shallow"
5	656,600	deep
6	132,190	"shallow"
7	392,925	deep
8	143,530	"shallow"
9	408,160	deep
Eastern Gulf of Alaska and west coast of N. America model (PROBUB 80-2)		
11	119,710	"shallow"
12	265,090	deep
13	38,170	"shallow"
14	260,160	deep
15	37,525	"shallow"
16	463,500	deep

Table 4.--Mean growth and mortality coefficients and food requirements for the PROBUB models 80-1 and 80-2.

Species/ecological groups	Species number	Growth coeff. inst. (monthly) *	Mort. coeff. inst. (monthly) **	Fishing mort. coeff. inst. (monthly) ***	Food requirements for maintenance % BWD ****	Food requirements for growth
	1					
	2					
	3					
(Hake	4)					
Greenland halibut, Pacific halibut	5	0.054	0.007	0.009	0.50	1.32
Flathead sole, arrowtooth flounder	6	0.055	0.008	0.0089	0.50	1.32
Yellowfin sole, rock sole, Alaska plaice	7	0.058	0.009	0.025	0.50	1.32
Other flatfishes	8	0.063	0.008	0.0050	0.51	1.32
Cottids, elasmobranchs and other demersal	9	0.068	0.009	-	0.54	1.67
Pacific cod, saffron cod	10	0.073	0.007	0.0062	0.54	1.63
Sablefish	11	0.072	0.006	0.019	0.54	1.67
Pollock	12	0.080	0.008	0.016	0.57	1.63
Pacific ocean perch + other rockfish	13	0.081	0.007	0.0081	0.51	1.50
Herring	14	0.092	0.006	0.0022	0.54	1.58
Capelin, sand lance	15	0.094	0.008	-	0.54	1.76
Atka mackerel	16	0.072	0.007	0.0022	0.54	1.50
Salmon	17	0.15	0.003	0.04	0.57	1.94
Squid	18	0.18	0.02	0.0015	0.51	1.94
Crab	19	0.06	0.007	0.0022	0.43	1.06
Shrimp	20	0.078	0.008	0.0002	0.43	1.23
Predatory benthos	21	0.070	0.008	-	0.43	1.58
Infauna	22	0.14	0.01	-	0.34	1.76
Epifauna	23	0.10	0.009	-	0.37	1.94

* - Annual mean, changes with temperature and starvation.

** - Annual mean, changes with subregions, temperature and severe starvation.

*** - The fishing mortality coefficient given here is for relative guidance only. Each subregion has been assigned proper monthly fishing mortality coefficient.

**** - Annual mean, changes with temperature.

Table 5.--Initial mean composition of food (in %) for coastal (shallow) and offshore (deep) subregions for PROBUB model 80-1

	Shallow	Deep
Turbot, halibut (5)		
Infauna	20	5
Epifauna	52.2	36.0
Euphausids	5	30
Cottids and other demersal	5.3	4
Flathead sole	1	0.3
Yellowfin sole	1.5	0.5
Other flatfish	1	0.4
Crab	1	1
Shrimp	2	1.3
Cod	2	3
Rockfish	2	4
Pollock	6	8
Squid	1	6
Salmon	0.5	0.5
Flathead sole (6)		
Infauna	18	3
Epifauna	42	22
Euphausids	9	45
Cottids and other demersal	9	9
Cod	4	4
Crab	3	1
Shrimp	3	2
Pollock	8	8
Other flatfish	2	2
Capelin and other pelagic	1	2
Rockfish	1	2

	Shallow	Deep
Yellowfin sole (7)		
Infauna	18	3
Epifauna	38.5	11.5
Euphausids	12	44
Copepods	5	25
Capelin and other pelagic	5	5.5
Cottids and other demersal	4	2
Rockfish	3	1
Crab	2	0.5
Shrimp	3	0.5
Cod	2	1
Other flatfish	2	0.5
Pollock	3	3
Squid	1	2
Flathead sole	1.5	0.5
Other flatfish (8)		
Infauna	22	4.5
Epifauna	39	16
Euphausids	13	46.5
Copepods	5	19
Capelin and other pelagic	4	3
Cottids and other demersal	5	2.5
Rockfish	2	1.5
Crab	1	0.5
Shrimp	2	0.5
Pollock	3	4
Herring	2	1.5
Yellowfin sole	2	0.5

Table 5 (Cont'd).

Cottids and other demersal (9)	Shallow	Deep
Infauna	10	3
Epifauna	25	6
Euphausids	22	41.5
Copepods	25	40
Turbot, halibut	0.5	0.1
Flathead sole	0.5	0.1
Yellowfin sole	0.5	0.1
Other flatfish	0.5	0.1
Cottids and other demersal	2.5	2.5
Cod	0.5	0.1
Pollock	2	1.5
Capelin and other pelagic	5	3.5
Crab	1	0.1
Shrimp	2	0.2
Rockfish	1	0.3
Herring	2	0.9

Cods (10)	Shallow	Deep
Infauna	6	1
Epifauna	18.45	6
Predatory benthos	6	2
Euphausids	19	32.8
Copepods	13	33.5
Crab	2	0.5
Shrimp	3.5	0.8
Pollock	7	6
Flathead sole	1	0.2
Yellowfin sole	1.8	0.4
Turbot, halibut	0.75	0.1
Cottids and other demersal	6	2.5
Squid	7	10
Herring	2	1
Capelin and other pelagic	5	3
Sablefish	1.5	0.2

Sablefish (11)	Shallow	Deep
Infauna	7	1
Epifauna	18.5	7
Predatory benthos	9	2
Euphausids	18	54.2
Shrimp	3	2
Pollock	15	11
Turbot, halibut	1.5	0.2
Flathead sole	2.5	0.2
Yellowfin sole	3.5	1.2
Other flatfish	2.5	0.2
Cottids and other demersal	8	2
Squid	6	10
Cod	4	2
Capelin and other pelagic	3	1.5
Rockfish	3.5	3.0
Sablefish	2	3

Pollock (12)	Shallow	Deep
Copepods	30	34
Euphausids	43.5	48.9
Pollock	8	9.4
Capelin and other pelagic	5	3
Herring	3	1
Cottids and other demersal	3	0.4
Epifauna	1.5	0.1
Rockfish	1.8	1.2
Shrimp	0.5	0.1
Flathead sole	0.2	0.1
Turbot, halibut	0.3	0.1
Yellowfin sole	0.6	0.2
Other flatfish	0.5	0.1
Atka mackerel	1.0	0.8
Crab	0.3	0.1
Cod	0.8	0.5

Table 5. (Cont'd).

	Shallow	Deep
Rockfishes (13)		
Copepods	22	32
Euphausids	38	42
Capelin and other pelagic	8	5
Squid	5	10
Cottids and other demersal	5	3
Epifauna	5	1
Herring	2	1
Pollock	4	2
Crab	1	0.2
Shrimp	2	0.3
Cod	3	2
Halibut, turbot	0.5	0.1
Yellowfin sole	0.5	0.1
Flathead sole	0.5	0.1
Other flatfish	0.5	0.1
Atka mackerel	3	1.1
Herring (14)		
Copepods	60	60
Euphausids	32	35.3
Capelin and other pelagic	3	1.7
Shrimp	0.5	0.1
Crab	0.5	0.1
Atka mackerel	1.5	0.8
Pollock	2	1.5
Rockfish	0.5	0.5

	Shallow	Deep
Capelin and other pelagic (15)		
Copepods	36	38
Euphausids	55	55.8
Herring	2	1
Pollock	2	2
Rockfish	1	1
Atka mackerel	1	1
Capelin and other pelagic	2	1
Other flatfish	1	0.2
Atka mackerel (16)		
Copepods	45	48
Euphausids	35.5	43
Capelin and other pelagic	5.5	2.5
Herring	1.5	0.5
Pollock	3.0	2.5
Rockfish	3.5	1.5
Turbot, halibut	0.5	0.1
Flathead sole	0.5	0.1
Yellowfin sole	0.5	0.1
Cottids and other demersal	3.5	1.5
Shrimp	0.5	0.1
Crab	0.5	0.1

Table 5 (Cont'd).

Salmon (17)	Shallow	Deep
Copepods	10	10
Euphausids	40	45
Herring	7	2
Atka mackerel	7	3
Capelin and other pelagic	10	4
Squid	12	28
Rockfish	4	2
Pollock	10	6

Squids (18)	Shallow	Deep
Copepods	11	14
Euphausids	32	40
Pollock	15	12
Atka mackerel	6	5
Capelin and other pelagic	6	6
Herring	4	2
Squid	23	20
Rockfish	3	1

Crabs (19)	Shallow	Deep
Infauna	32	30
Epifauna	39	30
Copepods	12.5	20
Euphausids	10	19.5
Shrimp	5	0.2
Yellowfin sole	0.5	0.1
Flathead sole	0.5	0.1
Other flatfish	0.5	0.1

Shrimps (20)	Shallow	Deep
Infauna	30	5
Epifauna	45	10
Copepods	13	50
Euphausids	12	35

Predatory benthos (21)	Shallow	Deep
Infauna	32	28.8
Epifauna	67	70.5
Cottids and other demersal	0.5	0.2
Shrimp	0.5	0.5

Infauna (22)	Shallow	Deep
Phytoplankton (detr.)	75	75
Copepods (detr.)	10	10
Euphausids (detr.)	10	10
Epifauna (detr.)	5	5

Epifauna (23)	Shallow	Deep
Infauna	40	40
Phytoplankton (detr.)	24	24
Euphausids (detr.)	18	18
Copepods (detr.)	18	18

Copepods and euphausids (25, 26)	Shallow	Deep
Phytoplankton	100	100

Table 6.--Harmonic constants for simulation of phyto- and zooplankton standing stocks in the eastern Bering Sea and western Gulf of Alaska.

Zooplankton constants

Areas	ZOO	ZOA	ZKA	ZOF	ZKF
1	600	102	200	52	200
2	520	78	220	35	190
3	560	62	175	40	185
4	640	85	155	45	185
5	590	70	145	42	195
6	660	85	150	55	185
7	590	60	155	48	175
8	680	90	135	55	180
9	550	60	150	45	175

Phytoplankton constants

Areas	PYO	PYA	PKA	PYF	PKF
1	1,700	650	175	200	195
2	1,500	420	185	180	175
3	1,650	500	160	180	190
4	1,750	620	130	220	185
5	1,780	540	140	180	190
6	1,780	610	125	220	190
7	1,650	560	137	180	180
8	1,850	610	132	220	190
9	1,700	560	148	200	180

Table 7.--Computed monthly growth coefficients of pollock and flathead sole in subregion 1 in the eastern Bering Sea.

	Monthly growth coefficient	
Month	Pollock	Flathead sole
January	0.0715	0.0477
February	0.0715	0.0491
March	0.0715	0.0491
April	0.0715	0.0491
May	0.0724	0.0498
June	0.0855	0.0588
July	0.0929	0.0639
August	0.0929	0.0627
September	0.0917	0.0631
October	0.0917	0.0617
November	0.0929	0.0639
December	0.0800	0.0617

Table 8.--Computed monthly growth coefficients of pollock and flathead sole in February and August in 9 subregions of the Bering Sea and Gulf of Alaska.

	Subregion								
Month	1	2	3	4	5	6	7	8	9
Pollock									
February	0.0715	0.0755	0.0724	0.0840	0.0763	0.0780	0.0768	0.0811	0.0811
August	0.0929	0.0903	0.0917	0.0870	0.0829	0.0831	0.0818	0.0846	0.0818
Flathead sole									
February	0.0491	0.0519	0.0462	0.0540	0.0488	0.0536	0.0487	0.0548	0.0517
August	0.0627	0.0621	0.0580	0.0564	0.0529	0.0571	0.0526	0.0570	0.0519

Table 9.--Examples of food composition changes in space and time in Pacific cod in shallow subregions.

		Food composition in %			
		Subregion 1		Subregion 6	
Food item (group)	Initial	March	September	March	September
Infauna	6	4.8	4.3	6.2	6.5
Epifauna	18.45	19.4	19.9	19.2	19.9
Predatory benthos	6	3.9	6.5	6.2	4.6
Euphausids	19	20.0	20.5	19.8	20.5
Copepods	13	13.7	14.0	13.5	14.0
Crab	2	2.1	2.2	2.1	2.2
Shrimp	3.5	3.7	2.6	2.6	2.5
Pollock	7	7.4	7.5	7.3	7.6
Flathead sole	1	1.1	1.1	1.0	1.1
Yellowfin sole	1.8	1.9	1.9	1.9	1.9
Turbot, halibut	0.75	0.8	0.8	0.8	0.8
Cottids and other demersal	6	6.3	6.5	6.2	6.5
Squid	7	4.2	3.0	4.2	2.9
Herring	2	2.1	2.2	2.1	2.2
Capelin and other pelagic	5	5.3	5.4	5.2	5.4
Sablefish	1.5	1.6	1.6	1.6	1.6
Starvation		1.7	0.1	0.2	0

Table 10.--Examples of food composition changes in space and time in Pacific cod in deep subregions.

		Food composition in %			
		Subregion 3		Subregion 7	
Food item (group)	Initial	March	September	March	September
Infauna	1	1.1	1.1	1.1	1.1
Epifauna	6	2.3	2.2	3.7	2.9
Predatory benthos	2	0.6	2.2	2.1	2.2
Euphausids	32.8	36.1	36.6	34.7	36.0
Copepods	33.5	36.9	37.3	35.4	36.7
Crab	0.5	0.2	0.2	0.5	0.5
Shrimp	0.8	0.9	0.4	0.8	0.5
Pollock	6	6.6	6.7	6.3	6.6
Flathead sole	0.2	0.1	0.1	0.2	0.2
Yellowfin sole	0.4	0.4	0.4	0.4	0.4
Turbot, halibut	0.1	0.1	0.1	0.1	0.1
Cottids and other demersal	2.5	1.1	1.2	0.9	0.9
Squid	10	11.0	5.0	10.6	5.3
Herring	1	0.6	0.5	1.1	1.1
Capelin and other pelagic	3	1.7	1.5	1.9	1.6
Sablefish	0.2	0.2	0.2	0.2	0.2
Starvation		0.1	4.3	0	3.7

Table 11.--Examples of food composition changes in space and time in flathead sole in shallow subregions.

		Food composition in %			
		Subregion 1		Subregion 6	
Food item (group)	Initial	March	September	March	September
Infauna	18	14.3	13.0	18.3	18.4
Epifauna	42	43.9	44.5	42.8	43.0
Euphausids	9	9.4	9.5	9.2	9.2
Cottids and other demersal	9	9.4	9.5	9.2	9.2
Cod	4	4.2	3.2	3.0	2.8
Crab	3	3.1	3.2	3.1	3.1
Shrimp	3	3.1	2.3	2.2	2.1
Pollock	8	8.4	8.5	8.2	8.2
Other flatfish	2	2.1	2.1	2.0	2.0
Capelin and other pelagic	1	1.0	1.1	1.0	1.0
Rockfish	1	1.0	1.1	1.0	1.0
Starvation		0.1	3.0	0	0

Table 12.--Examples of food composition changes in space and time in flathead sole in deep subregions.

		Food composition in %			
		Subregion 3		Subregion 7	
Food item (group)	Initial	March	September	March	September
Infauna	3	3.7	3.9	3.5	3.7
Epifauna	22	8.6	7.9	13.4	10.5
Euphausids	45	56.0	58.3	52.8	55.2
Cottids and other demersal	9	4.0	4.2	3.3	3.1
Cod	4	2.7	2.4	2.7	2.4
Crab	1	0.4	0.4	1.2	1.2
Shrimp	2	2.5	1.1	2.3	1.4
Pollock	8	10.0	10.4	9.0	9.8
Other flatfish	2	2.5	1.1	2.3	2.5
Capelin and other pelagic	2	1.1	1.0	1.2	1.1
Rockfish	2	1.2	1.0	2.3	2.5
Stavation		7.3	8.3	6.0	6.6